

REPORT NO. NADC-75205-30

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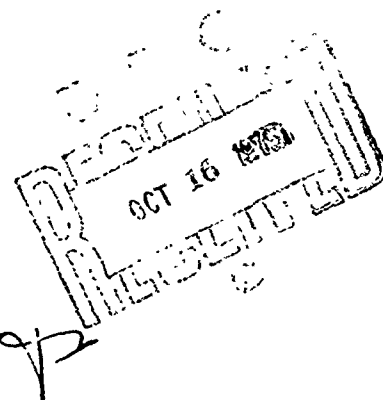


**STRESS CORROSION RESISTANCE OF 7050-T73
ALUMINUM ALLOY**

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10 September 1975

PROGRESS REPORT
AIRTASK NO. A3200000/001A/4-R02201001
Work Unit No. DG202



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Prepared for
NAVAL AIR SYSTEMS COMMAND
Department of the Navy
Washington, D. C. 20361

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4. TITLE (and Subtitle) STRESS CORROSION RESISTANCE OF 7050-T73 ALUMINUM ALLOY,		5. TYPE OF REPORT & PERIOD COVERED PROGRESS REPORT,
		6. PERFORMING ORG. REPORT NUMBER NADC-75205-30
7. AUTHOR(s) I. SHAFFER		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Air Development Center Air Vehicle Technology Department Warminster, Pennsylvania 18974		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AIRTASK A32 00000/001A/4- R02201001, Work Unit DG 202
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Air Systems Command Department of the Navy Washington, D.C. 20361		12. REPORT DATE 10 Sept 1975
		13. NUMBER OF PAGES 10
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
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18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Stress corrosion Aluminum alloys Exfoliation		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The objective of this investigation was to evaluate the stress corrosion behavior of the 7050 aluminum alloy in the overaged T73 heat treat condition. Stress corrosion tests were conducted using both smooth and precracked specimens. No evidence of stress corrosion was found in any of the tests conducted. The material also exhibited immunity to exfoliation in both salt spray and c... it immersion tests.		

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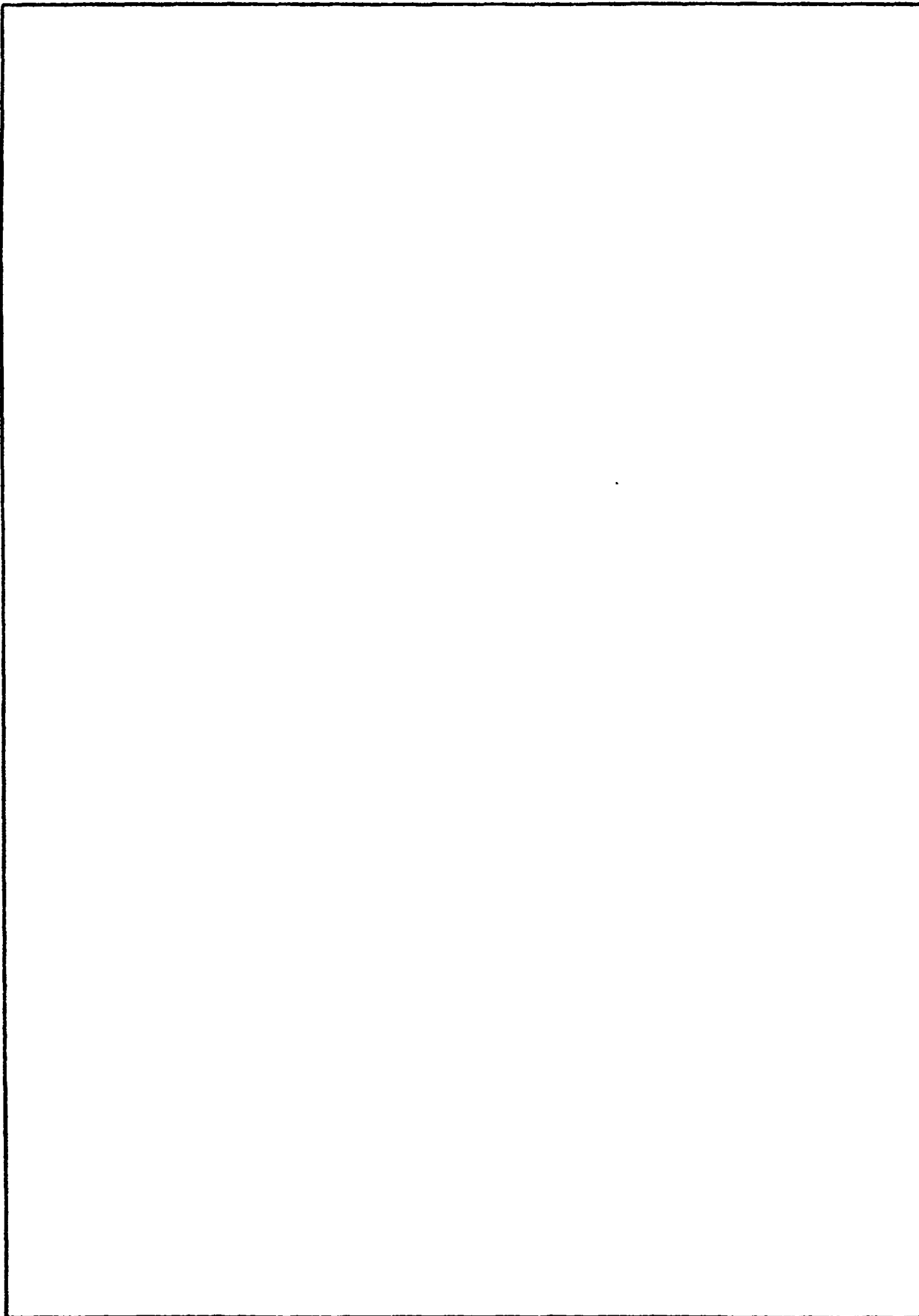
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I N T R O D U C T I O N

Alloy 7050, developed under contracts from the Naval Air Systems Command for use on advanced aerospace structures, has a combination of properties including: strength, fracture toughness and resistance to stress corrosion cracking which is superior to that provided by 7075. The object of this investigation was to further explore the susceptibility to stress corrosion cracking and exfoliation of this alloy in the T73 overaged condition.

The propensity for stress corrosion cracking was determined using both smooth and pre-cracked specimens exposed in different test media. A comparison of exfoliation resistance was made for 7050-T73651, 7075-T651 and 7075-T73 in salt spray and total immersion tests. This project was performed under AIRTASK A32 00000/001A/4-R02201001 as part of the continuing program of evaluating new developments in aluminum alloys.

This new 7000 series alloy, 7050, is a result of an Alcoa Research Laboratory discovery that a change in the ratios of Zn, Mg, and Cu contents coupled with an addition of Zr in lieu of Cr has unique effects on the characteristics of Al-Zn-Mg-Cu alloys.

E X P E R I M E N T A L P R O C E D U R E

MATERIAL

The 7050 material utilized in this investigation was taken from a 4 in. thick experimental plate in the T73651 temper and a 2 in. thick plate of T736. The chemical compositions and tensile properties for this material are listed in Table I. Tensile specimens of 1/8 in. diameter were fabricated with their lengths parallel to the short transverse direction of the 4 in. plate. The double cantilever beam (DCB) pre-cracked stress corrosion specimens, as shown in Figure 1, were taken from the center of the 2 in. plate with the length oriented parallel to the rolling direction (S-L)

Stepped panels were machined to expose the T/10, T/4 and T/2 planes. Sections from expended DCB specimens also were used for determining exfoliation propensity.

STRESS CORROSION TESTS

The smooth tensile bar specimens were stress corrosion tested in the 3.5% NaCl alternate immersion tests in accordance with Federal Test Method Standard 151 (Method 823). The specimens were loaded to stress levels ranging from 50 to 85 percent of the short transverse yield strength of the 7050-T73651 plate. Three of the specimens were chromate conversion coated as per MIL-C-81706 to further compare the beneficial effects of this procedure in reducing pitting attack on stress corrosion specimens, as was reported in reference (a). To afford an additional comparison specimens of 7075-T73 also were tested.

The DCB specimen used in this study was the one adapted for stress corrosion testing of aluminum alloys by Hyatt (reference (b)). This is a self-loaded

TABLE I

CHEMICAL COMPOSITIONS AND TENSILE PROPERTIES FOR THE 7050-T73 PLATE

<u>MATERIAL</u>	<u>CHEMICAL COMPOSITION, WEIGHT PERCENT</u>							
	<u>Si</u>	<u>Fe</u>	<u>Cu</u>	<u>Mn</u>	<u>Mg</u>	<u>Cr</u>	<u>Zn</u>	<u>Ti</u> <u>Zr</u>
4 in. Plate	0.05	0.09	2.17	0.03	2.34	0.02	6.10	0.03 0.11
2 in. Plate	0.05	0.10	2.09	0.01	2.27	0.04	6.00	0.03 0.11

<u>TENSILE PROPERTIES</u>			
	<u>Tensile Strength</u>	<u>Yield Strength</u>	<u>Elongation</u>
	<u>(ksi)</u>	<u>(ksi)</u>	<u>(%)</u>
4 in. plate (short transverse)	73.0	57.6	8
2 in. plate (longitudinal)	74.2	64.7	12

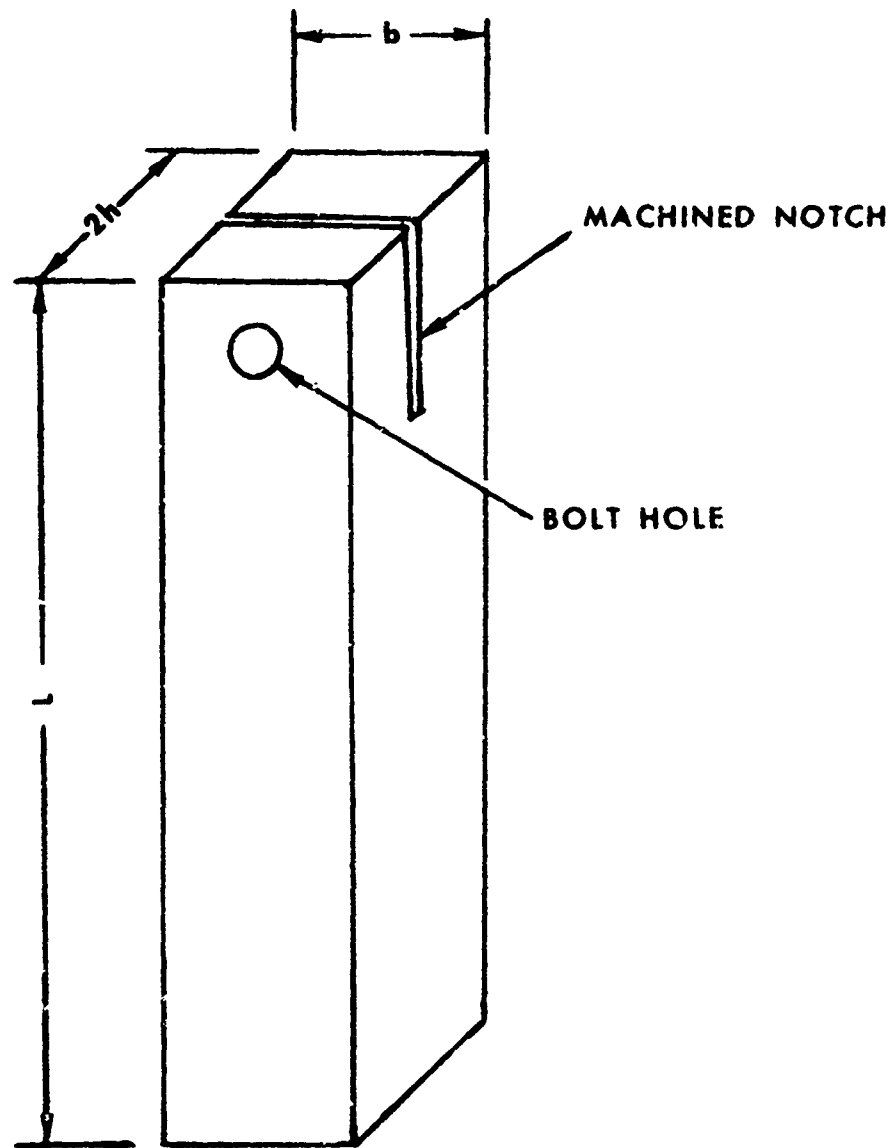


Figure 1. Double Cantilever Beam Stress Corrosion Cracking Specimen

specimen in which the stress is applied by turning the opposing bolts in equal amounts until a crack is "popped in" at the base of the machined notch. By measuring the crack length and the total deflection of the two arms of the DCB specimen at the load line, the stress intensity (K_I) is then calculated using the equation:

$$K_I = \frac{\sqrt{3} E h \left[3h(a + 0.6h)^2 + h^3 \right]^{\frac{1}{2}}}{4 \left[(a + 0.6h)^3 + h^2 a \right]}$$

where δ = deflection at the load line
 h = height of specimen
 a = crack length
 E = Young's Modulus

In several specimens the root of the machined notch was sharpened by fatigue precracking prior to loading. The procedure was performed to facilitate "pop-in" with the high toughness 7050 material.

The stress corrosion tests were conducted by placing the loaded DCB pre-cracked specimens in beakers of 3.5% NaCl or synthetic sea salt solution. The specimens were placed carefully in the solutions so that the crack was immersed but the loading bolts remained dry above the solution level to prevent any galvanic corrosion from influencing the test results.

EXFOLIATION TESTS

The exfoliation test specimens were exposed to the Synthetic Sea Salt - SO_2 salt spray environment for one week. Details of this test method along with the rationale for its development have been presented in earlier studies (references (c) and (d)). Supplementary exposures were made in the constant immersion EXCO Test, ASTM Test Method G34-72.

RESULTS AND DISCUSSION

The results of the stress corrosion alternate immersion tests are listed in Table II. For the bare 7050-T73651 specimens no failures occurred at stresses below 43 ksi or in less than 36 days. A metallographic examination was made on the three fractured specimens to determine the failure mechanisms. The secondary cracks found were not typical of the intergranular stress corrosion cracking that occurs in susceptible 7000 series aluminum alloys. In each specimen cracks had initiated almost exclusively from deep corrosion pits and tended to propagate in a transgranular mode, as can be seen in the photomicrographs of Figure 2. The failures were caused by a combination of deep directional pitting and tensile overload as a result of the reduction in cross sectional area.

No failures developed in the 7050 specimens coated with the chromate conversion coating. Several of the unfailed bare and coated specimens mechanically fractured during unloading of the stressing frames. Tensile tests were performed on the remaining specimens and this data is provided in Table III. A comparison of these results for the bare and coated specimens shows an average reduction in ultimate tensile strength of 40 and 13 percent respectively.

TABLE II

RESULTS OF 3.5% NaCl ALTERNATE IMMERSION TESTS

<u>Specimen</u>	<u>Surface</u>	<u>Stress</u>		<u>Days to Failure</u>
		<u>% YS</u>	<u>ksi</u>	
1	Bare	85	49	42
2	"	85	49	36
3	"	75	43	58
4	"	75	43	NF 90 days
5	"	60	34	
6	"	60	34	
7	"	50	29	
8	"	50	29	
9	Chromate Conversion Coated	75	43	
10	"	75	43	
11	"	75	43	
7075-T73				
27	Bare		43	
40	"		43	
77	"		43	



etch

100x

specimen #1 - stressed at 49 ksi and failed after 36 days



Modified
Keller's
Etch

100x

specimen #3 - stressed at 43 ksi and failed in 58 days

Figure 2. Photomicrographs showing secondary cracks propagated from deep corrosion pits.

TABLE III

TENSILE TEST RESULTS FOR THE UNFAILED STRESS CORROSION SPECIMENS

<u>Specimen</u>	<u>Surface</u>	<u>Tensile Strength (ksi)</u>	<u>% Reduction</u>	<u>Yield Strength (ksi)</u>	<u>% Reduction</u>
5	Bare	43.5	40	42.1	28
6	"	43.6	40	41.3	28
10	Chromate conversion coated	65.9	13	57.4	4
11	"	60.6	13	54.1	4

The data further confirm the findings in reference (a) that chromate conversion coatings provide a beneficial effect when used on stress corrosion specimens, by alleviating nuisance failures, those caused by pitting corrosion or mechanisms other than stress corrosion cracking.

The excellent stress corrosion resistance displayed by the 7050 material correlates with the observations made by Staley (reference (e)) for 7050 forging. His results indicated that stress corrosion performance for this alloy decreased with increasing short transverse yield strength. All stress corrosion specimens machined from low yield strength material, approximately 60 ksi, survived a one-year exposure in an industrial atmosphere. For the highest strength forgings evaluated, those with a short transverse yield strength of 75 ksi, only 50% of the specimens stressed at 25 ksi survived the one-year test.

The specimens of 7075-T73 also did not fail in this 90-day test. An optical examination at the completion of the test indicated less severe pitting attack on the 7075-T73 specimens as compared to those of 7050-T73651.

In agreement with the tests on the smooth tensile bar specimens, no stress corrosion cracking was found in the precracked DCB specimens in either test environment. In the 1000 hour test durations no crack growth was measured on any of the 7050 DCB specimens. Since these data were generated, Jones (reference (f)) has published results on the effect of corrosive environment on stress corrosion of 3 in. thick 7050-T73651 plate. In tests conducted with compact tension fracture mechanics specimens a slight stress corrosion susceptibility was detected in 3.5% NaCl alternate immersion but no crack propagation occurred in stagnant and flowing 3.5% NaCl and in sump tank water (ref.(f)).

Considerable plastic deformation occurred at "pop-in" on all the specimens, even those in which the mechanical notch was sharpened by fatigue precracking. This is apparently due to the good toughness properties of the 7050 alloy. The mechanical cracks that did form were transgranular and tended to run out of plane.

No exfoliation occurred in any 7050 specimen tested. Figure 3 shows a comparison between stepped panels of 7075-T651, 7075-T73 and the 7050-T73651 exposed in the SO₂-Synthetic Sea Salt Spray test for one week. This harsh test environment produced severe exfoliation in the 7075-T651 material and extensive pitting corrosion on the two overaged specimens. It was noted that slightly larger and deeper pits developed on the 7050-T73651 as compared to the 7075-T73.

C O N C L U S I O N S

The aluminum alloy material 7050-T73 exhibited no susceptibility to stress corrosion cracking in tests with both smooth and pre-cracked specimens.

The chromate conversion coating alleviated pitting attack on stress corrosion specimens in the 3.5% NaCl alternate immersion test making crack detection easier.

The 4 in. and 2 in. plates of 7050 were judged immune to exfoliation.

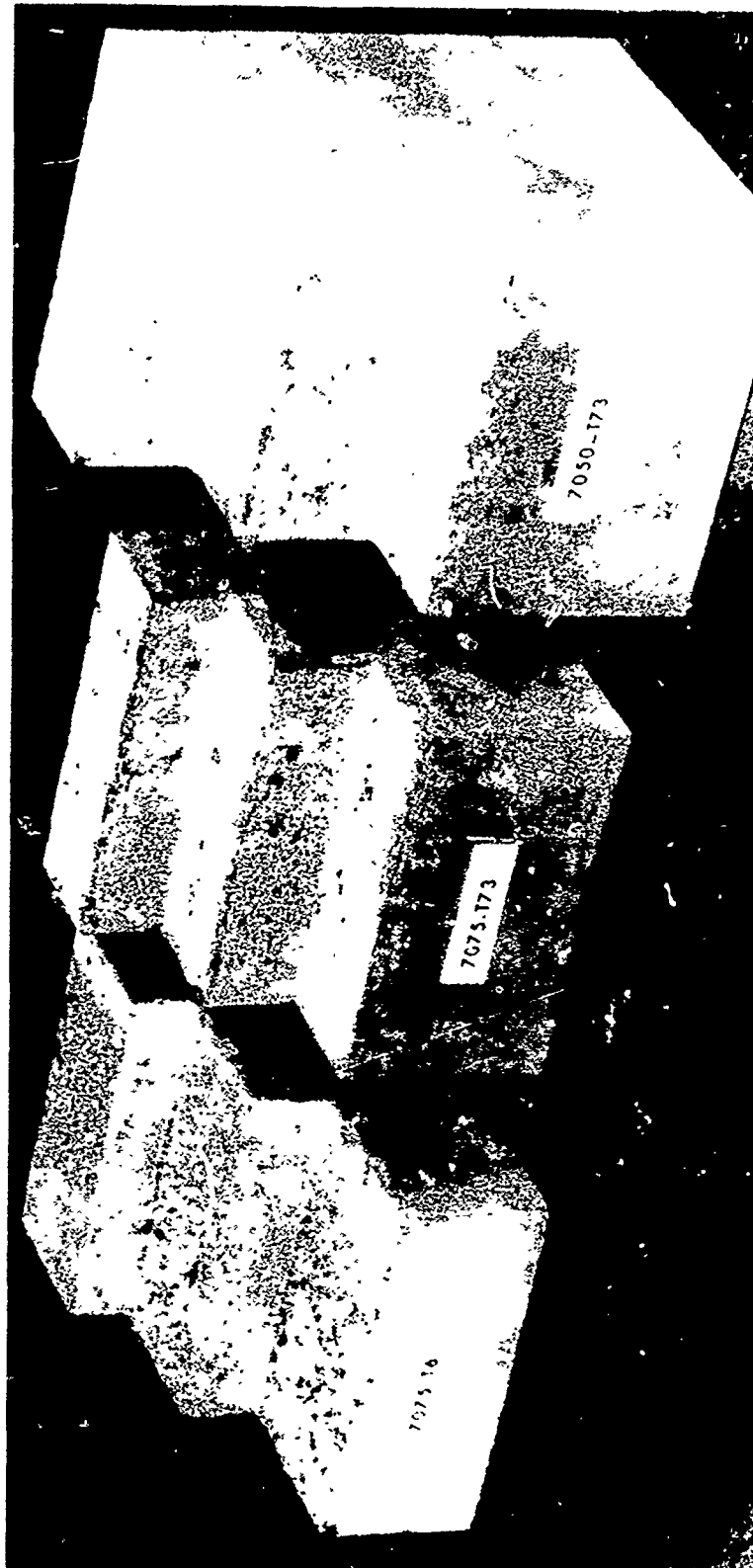


Figure 3. Stepped Panels after One-Week Exposure in SO₂-Synthetic Sea Salt Spray Test

R E C O M M E N D A T I O N S

Due to its excellent combination of fracture toughness, strength and resistance to stress corrosion cracking the high strength aluminum alloy 7050-T73 is recommended for use in naval aircraft structures.

R E F E R E N C E S

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